Elliptic flow from pQCD+saturation+hydro model

K J Eskola, H Niemi and P V Ruuskanen

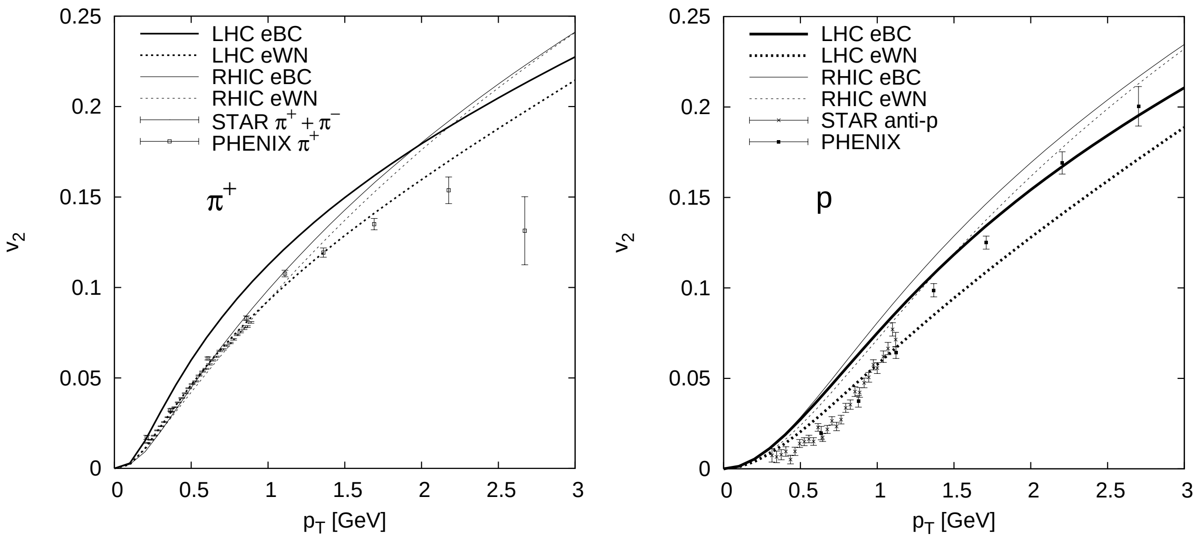
Department of Physics, University of Jyväskylä, Finland

Helsinki Institute of Physics, University of Helsinki, Finland

We have previously predicted multiplicities and transverse momentum spectra for the most central LHC Pb+Pb collisions at $\sqrt{s_{NN}} = 5.5$ TeV using pQCD + saturation + hydro (EKRT model) [1, 2]. We now extend these calculations for non-central collisions and predict low-p_T elliptic flow. Our model is in good agreement with RHIC data for central collisions, and we show that our extension of the model is also in good agreement with minimum bias v_2 data from RHIC Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV.

We obtain the primary partonic transverse energy production and the formation time in central AA collisions from the EKRT model [2]. With the assumption of immediate thermalization we can use these to estimate the initial state for hydrodynamic evolution. For centrality dependence we consider here two limits which correspond to models eWN and eBC in [3], where the profile and normalization are obtained from optical Glauber model, once the parameters in central collisions are fixed. In the eWN (eBC) model the energy density profile and normalization are proportional to the density and the number of wounded nucleons (binary collisions), respectively. These energy density profiles are used to initialize boost invariant hydro code with transverse expansion. We use the bag model equation of state with massless gluons and quarks ($N_f = 3$), and hadronic phase with all hadronic states up to a mass 2 GeV included. Phase transition temperature is fixed to 165 MeV. Decoupling is calculated using standard Cooper-Frye formula, and all decays of unstable hadronic states are included. Freeze-out temperature is fixed from RHIC p_T spectra for the most central collisions and is 150 MeV for binary collision profile [1] and 140 MeV for wounded nucleon profile. The same freeze-out temperatures are used at the LHC. Both initializations give a good description of the low-p_T spectra for different centralities at RHIC.

Left figure shows our calculations for p_T dependence of minimum bias v_2 for positive pions. RHIC results are compared with STAR [4] and PHENIX [5] data. Our minimum bias centrality selection $(0 - 80\%)$ corresponds to the one used by STAR collaboration. Solid lines are calculations with the eBC model and dashed lines are from the eWN model. Thin lines are our results for RHIC Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV and thick lines show our predictions for the LHC Pb+Pb collisions at $\sqrt{s_{NN}} = 5.5$ TeV. Largest uncertainty in v_2 calculations for pions comes here from the initial transverse profile of the energy density. Sensitivity to initial time and freeze-out temperature is much weaker. In general the eWN profile leads to weaker elliptic flow than the eBC



profile. At the LHC the lifetime of the QGP phase is longer, which results in stronger flow asymmetry than at RHIC. On the other hand the magnitude of transverse flow is also larger, which decreases the v_2 value at fixed p_T. The net effect is that, for a given profile, v_2 of low-p_T pions is larger at the LHC than at RHIC. Since jet production at the LHC starts to dominate over the hydrodynamic spectra at larger p_T than at RHIC [1], we expect that the hydrodynamic calculations should cover a larger p_T range at the LHC. Thus we predict that the minimum bias v_2 of pions at fixed p_T is larger at the LHC than at RHIC, and can reach values as high as 0.2.

Our model clearly overshoots the proton v_2 data from STAR [4] and PHENIX [5]. A more detailed treatment of the hadron gas dynamics and freeze-out is needed to describe both the proton spectra and elliptic flow simultaneously. However, we can still predict the *change* in the behaviour of v_2 of protons when going from RHIC to the LHC. This is shown in the r.h.s. figure. Although the flow asymmetry increases at the LHC, for more massive particles like protons the overall increase in the magnitude of radial flow is more important than for light pions. This results in smaller v_2 at the LHC than at RHIC in the whole p_T range for protons. Even if v_2 at fixed p_T is smaller at the LHC, p_T-integrated v_2 is always larger at the LHC for all particles, due to the increase in the relative weight at larger p_T's.

References

[1] K. J. Eskola, H. Honkanen, H. Niemi, P. V. Ruuskanen and S. S. Räsänen, Phys. Rev. C **72** (2005) 044904 [arXiv:hep-ph/0506049].

[2] K. J. Eskola, K. Kajantie, P. V. Ruuskanen and K. Tuominen, Nucl. Phys. B **570** (2000) 379 [arXiv:hep-ph/9909456].

[3] P. F. Kolb, U. W. Heinz, P. Huovinen, K. J. Eskola and K. Tuominen, Nucl. Phys. A **696** (2001) 197 [arXiv:hep-ph/0103234].

[4] J. Adams *et al.* [STAR Collaboration], Phys. Rev. C **72** (2005) 014904 [arXiv:nucl-ex/0409033].

[5] S. S. Adler *et al.* [PHENIX Collaboration], Phys. Rev. Lett. **91** (2003) 182301 [arXiv:nucl-ex/0305013].